DOCUMENT RESUME

ED 456 032 SE 065 084

AUTHOR del R. Medina-Diaz, Maria; Echegaray, Francisco; Motta, Noel
TITLE Formative Evaluation of the Project Enhancement of Problem Solving and Scientific Reasoning Skills through Computerized General Chemistry Modules.
SPONS AGENCY Fund for the Improvement of Postsecondary Education (ED), Washington, DC.
PUB DATE 2000-06-00
NOTE 28p.; Also supported by the University of Puerto Rico, President's Office.
PUB TYPE Reports - Evaluative (142)
EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Chemistry; Computer Uses in Education; *Educational Technology; Higher Education; *Learning Modules; *Problem Solving; Science Education; *Thinking Skills
IDENTIFIERS Puerto Rico

ABSTRACT

This paper reports on the formative evaluation results of the project "Enhancement of Problem Solving and Scientific Reasoning Skills through Computerized General Chemistry Modules." This project includes the design, development, and implementation of two interactive computer modules for the enhancement of mathematical and problem solving skills of undergraduate students who are taking general chemistry courses at the University of Puerto Rico. Studies have shown that there is a correlation between students' performance and their math skills. The modules, Introductory and Equilibrium, were designed and written in Spanish, then translated into programming language. The Introductory module includes math skills, graphs, and problem solving. For the evaluation process, the first trial used a single experimental group with a pre-post test while the second trial used a pre- and post-test between an experimental and control group. (YDS)

Formative evaluation of the project Enhancement of problem solving and scientific reasoning skills through computerized General Chemistry modules[1]

María del R. Medina-Díaz[2], Francisco Echegaray & Noel Motta
University of Puerto Rico, Río Piedras Campus

Summary

This report details the formative evaluation results of the pilot implementation of the project *Enhancement of problem solving and scientific reasoning skills through computerized General Chemistry modules.* This project consists in designing, developing and implementing two interactive computer modules, *Introductory* and *Chemical Equilibrium*, for enhancing mathematical and problem solving skills in undergraduate students taking the General Chemistry course at the University of Puerto Rico, Rio Piedras Campus (UPR-RP). Both modules were designed and written in Spanish by the two faculty coordinators of the project (the second and third author of this paper) and translated to a programming language and software format by the company ACO Digital. Both modules are written in Spanish and are available upon request.

The evaluation process was undertaken during the pilot implementation of the *Introductory* module in two trials or stages during the academic year 1999-2000. In the first trial (first semester), a sample of 10 voluntary undergraduate students enrolled in a section of General Chemistry at the UPR-RP completed the work on the module in 17 computer sessions. In the second trial (second semester), a group of 32 General Chemistry's students used the module in 54 sessions. In both sections, the students worked individually through the module in the

[1] This proyect was funded by a grant from the Fund for the Improvement of Post Secondary Education (FIPSE) of the Department of Education of the United States and the University of Puerto Rico, President's Office.
[2] María del R. Medina-Díaz was the external evaluator, and Francisco Echegaray and Noel Motta, are the project's coordinators.

scheduled time. In all sessions, one of the project's coordinator was present and assisted the students.

The main results of this evaluation were the following:

1. The students spent approximately a total of six hours working on the *Introductory* module.
2. In both trials, all users indicated that the module's directions and explanations were clear, the examples were helpful and the vocabulary was easy to understand.
3. They used all or almost all of the information and helping devices in the screens.
4. Eighty-percent of the students praised the module as excellent because of its features. However, one of the features that most disliked was the text extension of the introductory explanations.
5. The students were interested in their work on the module and they highlighted that it helped to improve their math skills.
6. The students made several suggestions to improve the module and these were solved.
7. Non-significant differences were found in the pre- and post-test scores of the single sample. In the second trial, significant differences were found between the post-mean scores of the experimental and comparison group in the mathematics test.
8. Non-significant differences were found between the experimental and comparison group in the final exam but the mean score of the experimental group was higher than of the comparison group.

However, it should be noticed that some variables may influence the test scores of both groups: (1) different teaching styles, (2) sample selection and assignment to the groups, (3) changes in testing, (4) students' attitudes towards treatment, and (5) treatment briefly applied. Some recommendations are also included.

Introduction

Evaluation of instructional technology is essentially no different from evaluation of any sort of teaching and learning, and it should not be a casual process. In the field of educational evaluation, the evaluation of the student learning has been the most salient endeavor. There is often little attention and evaluation to the teachers' course materials and their usage in the classroom. As instructional technology has evolved, it has been subject to evaluation scrutiny. Today, more classroom teachers are using different kinds of technologies as instructional tools and it is necessary to evaluate their effectiveness in a systematic way.

According to Hancock (1977), evaluation of instructional technology must describe, as much is possible, what is happening; suggest possible changes that may lead to its improvement; and provide adequate information to assist the policy-making. Such evaluation can be performed with two approaches: formative and summative. Formative evaluation provides information about how well the instructional program is implemented and this information can be used for reaching conclusions regarding its merits. This evaluation aids to determine its weaknesses so that revisions can be made to make it more effective.

On the other hand, summative evaluation primarily focuses on the end product or outcome of the instruction. It provides an understanding of how a given instructional program reaches its goals and the findings assist the decision-makers to take decisions regarding its continuation. Steinberg (1991) points out that documentation regarding summative evaluation rarely accompanies computer and other technology lessons. The same tradition sustains for the minimal evaluation of other instructional materials such as textbooks.

In this instance, a formative evaluation was conducted during the pilot implementation of the *Introductory* module, which is part of project *Enhancement of problem solving and scientific reasoning skills through computerized General Chemistry module*. The focus of this evaluation was on determining the extent to which the project activities were conducted as planned and on providing information of its progress towards the goals and objectives. The evaluation was conducted for an external evaluator with strong collaboration of the project coordinators. In order to pursue the formative evaluation process, the following steps were taken: (1) Establishing the project's goals, (2) Formulating the evaluation questions, (3) Selecting the design of evaluation, (4) Developing data collection instruments, (5) Collecting and analyzing data, and (6) Reporting results, conclusions and recommendations. These steps are similar to those suggested by Fitz-Gibbon & Morris (1987); King, Moris & Fitz-Gibbon(1987); Popham (1988); and Worthen, Sanders & Fitzpatrick (1997).

Other approaches have been proposed to pursue formative evaluation of instructional products. For example, Smith & Ragan (1993) have elaborated a comprehensive four-stage procedure which includes (1) design review (revisions of goals, learner and context analysis, task analysis and specifications prior the development of the material in order to confirm the accuracy of the design); (2) expert reviews (content revisions of various specialists in order to check the accuracy and completeness of the material); (3) learner validation (tryout the material with a small group of the target audience for determining and rectifying problems in the instruction delivery); and (4) ongoing evaluation (subsequent revisions of the material usage according to the changes in the instructional context). However if time and money are short, the formative evaluation may include at least learner validation or field-testing. Accordingly, the stages 1, and 2 were performed in the development of the computerized modules. The Smith &

Ragan's stage 3, learner validation, is the crux of the formative evaluation of this project.

Project description

The project *Enhancement of problem solving and scientific reasoning skills through computerized General Chemistry modules* was an intitative of the two coordinators to help improve student performance in the General Chemistry Course. Studies in the UPR-RP Chemistry Department have shown that student performance in this course was significantly related to the students math skills. Also in other universities, problem-solving skills have been identified as one of the main barriers for reaching a satisfactory performance in the General Chemistry course. During the last two decades, the Chemistry Department of the UPR-RP has implemented various programs directed to increase students' success in the General Chemistry course such as the Personalized System of Instruction, and Pre-chemistry and Study Skills workshops. This project is the most recent and cost-effective initiative for reaching out students who need to improve math and problem solving skills. It includes designing, developing and implementing two interactive computer modules (*Introductory*, which includes Math Skills, Graphs and Problem Solving, and the *Chemical Equilibrium*) with the intent of enhancing problem solving skills and critical thinking in a context of solving numerical and conceptual problems.

The intention of the *Introductory* module is to provide students the necessary mathematical skills and guidelines for solving problems related to General Chemistry. It is divided in two tutorial sections written in Spanish. *Math Skills and Graphs*, and *Problem solving*. The *Math Skills* and *Graphs* section presents basic content information ranging from 2 to 8 pages and includes from 2 to 6 problems related to each of the following topics: ratios and proportions, percentages, algebraic equations, logarithms, scientific notation and graphs (See Table 1). All of the working screens with the problems also have available the following information devices: "Factores de conversión" (Conversion factors), "Fórmulas" (Formulae), "Tabla periódica" (Periodic table), and "Constantes físicas y químicas" (Physical and chemical constants). Helping device buttoms such as, "Sugerencias" (Suggestions) and "Dedo de la mano" (Hand finger), offer suggestions for solving the problems in this section.

Table 1. Components of the *Introductory* module

Introductory module sections	**Number of introductory pages per section**	**Number of exercises**
1. Math skills - Ratio and proportions	3	4
- Percentages	2	4
- Algebraic equations	2	4
- Logarithms	4	6
- Scientific notation	4	4
- Graphs	8	2
2. Problem Solving	12	9
Totals	35	33

The purpose of the *Math Skills* part is that students review and apply the basic math algorithms related to scientific notation, ratio and proportions, percentages, algebraic equations, logarithms in a set of problems to be solved. The reviews included examples are provided to illustrate the concepts and procedures. The *Graphs* part of the module emphasizes data representation and interpretation.

The *Problem Solving* section includes an introduction menu with the skills required to solve problems: (1) "Extracción de datos y visualización" (Data extraction and visualization),

(2) "Reconocimiento de incógnita" (Identify the unknown), (3) "Análisis y desarrollo de la estrategia" (Analysis and Strategy Development), (4) "Planteamiento de la solución escrita"(Statement of a solution), and (5) "Resolución matemática y metacognición" (Mathematical solution and metacognition). Each of these skills is explained in several pages and examples are provided, some of these being interactive. Also, this section contains nine practice problems. All the working screens, contain information and helping devices. The information options were the same as in the *Math skills* section. The help buttons were "Bombilla" (Light bulb) for extracting data, "Lápiz" (Pencil) for making a diagram, and "Nube" (Cloud) for analysis questions.

Project's Goals, objectives and activities

The project's goals and objectives are the following:

Goal #1: Improve academic performance of the UPR-RP students in the General Chemistry course.

Objective #1: Implement modules in the General Chemistry course

Goal #2: Improve academic performance of transfer students

Objective #2: Provide access to other institutions.

In order to achieve these, the following main activities were planned:

1) Design and prepare modules in computer language

2) Provide access to modules to students in a pilot group

a) Set up computers with the modules

b) Write a guide for the general use of the modules

c) Training students in the use of modules

Evaluation questions

The set of questions that guided the pilot study of the project were the following:

1. Were the project activities implemented as intended and according to the proposed timeline? If not, what changes were needed in the project implementation?
2. How much time did it take for students to complete the module?
3. Did the students complete the module successfully within the scheduled time?
4. What were the students' opinions about the module's features?
5. How relevant was the use of the module for students taking the General Chemistry course?
6. Overall, how did the students evaluate the module?
7. Did the students improve their scores from the pre-test to the post-test?
8. How was the students' performance in the final exam and in the General Chemistry course?

Evaluation desing

In order to answer these questions two designs were used for evaluating formatively the *Introductory* module implementation: (1) a single group pre-post test in the first trial, and (2) a pre- and post- test between an experimental and comparison group in the second trial.

In the first trial, a group of 21 undergraduate students enrolled in a section of General Chemistry voluntered for using the module at least once. They worked individualy through the module weekly in the scheduled hours. Ten out of the 21 (48%) students successfully completed the *Introductory* module in the first semester. All of these were first or second year students in a Natural Sciences undergraduate program. In the second semester, 32 out of 38 (84%) students in a section of General Chemistry used the module ("Experimental group"). Another section of twenty-one General Chemistry students was the "Comparison group". Both groups included second, third and four year students in the Natural Sciences and Education undergraduate programs. According to the following data, both groups were similar in their math and science background (See Table 2). The coordinators informed the students about the purpose of the project and they signed a consent form to participate.

Table 2. Characteristics of the students in the second trial

Characteristics	Groups	
	Comparison	Experimental
Undergraduate major:		
Natural Sciences	10 (48%)	21 (72%)
Education	11 (52%)	8 (38%)
Year of sudy:		
First	3 (14%)	10 (31%)
Second	4 (19%)	8 (25%)
Third	6 (29%)	6 (19%)
Fourth	3 (14%)	4 (13%)
Fifth or more	5 (24%)	4 (13%)
Courses approved:		
Pre-calculus	20 (95%)	20 (69%)
Calculus	6 (29%)	13 (45%)
Other Science courses	19 (90 %)	4 (13%)
Times in the General Chemistry course:		
First time	6 (29%)	8 (28%)
Second time	12 (57%)	16 (55%)
Third time	2 (9%)	5 (17%)
Fourth time	1 (29%)	0 (0%)
Total sample	21	29*

Note. * Twenty nine out of 32 answered the questions.

Data collection instruments

A brief description of all the instruments used for the formative evaluation follows. A mixed-method approach was employed combining quantitative and qualitative data collection instruments. All of the instruments were written and answered in Spanish. They are available upon request.

1. Attendance sheet

Every time a student attended to the computer sessions, the professor in charge checked the student name in the Attendance Sheet and the part of the module that he or she completed. This sheet helps to keep track of the sections and problems where each student was working.

2. Instructor's observations notes

In order to find out areas of weaknesses for improving the module execution, the students were observed and asked to point out to the professor in charge any problem, error or misunderstanding while they were working on the module. The professor in charge took notes of the student's findings and of his owns. The two professors in charge of attending to the sessions completed an observation data sheet.

3. Pre- and post-test

In the first trial, a pre- and post-test of math skills was administered to the students. It included a total of 30 multiple-choice items divided in six sections. Five items represented each of the six topics: Scientific notation, Equations, Ratio and proportions, Percentages, Logarithms and Graphics. The total score of both tests was 30. The order of some items and of the two parts of the pre-test was changed in the post-test. However, both tests covered the same topics and skills, and was based on the same set of specifications (See Table 3).

Table 3. Pre- and post-test blueprint in the first and second trial

Test topics	**Skills**	**Number of items (first trial)**	**Number of items (second trial)**
1. Scientific notation	-Express a number in scientific notation and vice versa	5	4
2. Equations	-Find solutions to linear and quadratic equations	5	4
3. Ratios and Proportions	-Find one value in the proportion	5	4
4. Percentages	-Determine the percentage of an amount -Determine the number related to a percentage - Find the total amount	5	4
5. Logarithms	-Find the logarithm and antilog of an expression -Identify logarithms rules - Solving equations with logarithms	5	4
6. Graphs	-Interpret information - Identify the appropriate scale -Identify variables and coordinates	5	5
7. Problem solving	- Data extraction - Identify unknown - Develop a strategy - Solving the problem - Revising the solution	0	5
Total		30	30

Because of the project's objective in determining the effect of module use on students' problem solving skills, the pre- and post-test were modified to include five problem-solving items in the second trial. The number of items in the five math skills was reduced to four, and five items represented graphs and problem solving skills. Alternate forms were administered as pre- and post-test to both groups. These forms have similar mean and standard deviation.

4. Interview

In the first trial, two samples of ten students were interviewed individually after they finished working on the modules. The first sample of ten students was selected at random after they completed the *Math* section of the *Introductory* module. The other group of interviewers was all the students who completed the *Problem Solving* section. Twenty-two questions were included in the interview questionnaire for collecting students' data about module's features and operation. The interview setting was the backside of the computer room and lasted approximately 15 minutes.

A sample of 16 out of 32 students was interviewed in the second trial. The interview was performed individually after they completed the work on the *Problem solving* section of the module, and scheduled at the student convenience. The interview questions were the same as before and the interviews were held in the computer room.

5. Users' evaluation questionnaire

A 29-item questionnaire was designed to collect information with regard to users' opinion about the *Introductory* module quality and usefulness. In the first trial, this instrument was administered at the end of the semester and answered by 11 students who used both sections of the module. During the second semester, 28 out of 32 students (88%), who completed the module, answered the questionnaire.

Data analysis

The responses of the two samples of students, who completed the work through the *Introductory* module in the first and second trial, were used in the statistical and the narrative data analysis. In the second trial, the pre- and post-test data of the 32 students were compared with a cohort group of 21 students. Descriptive statistics, Cronbach's internal consistency reliability indexes and item difficulties were calculated for each test. Also, Pearson's correlation indexes were computed using the students' scores in the pre- and post-test, final exam and course grade. A t-test was performed for determining the differences in mean scores of the experimental and comparison groups. The program GB-STAT for Mac was used in the statistical analysis.

Results

This section of the report includes the relevant results and interpretations related to the evaluation questions proposed. These are identified by the relevant variables of the questions.

Project activities and changes made

The main activities for the first year of the project were performed as planned: (1) to desing and develop the *Introductory* module, and (2) to provide access to students. The *Introductory* module (which includes *Math Skills*, *Graphs* and *Problem Solving*) was designed by the coordinators of the project on time, and translated to a computer-programming language accordingly by the company ACO Digital. The *Introductory* module is available in PC format upon request and the *Chemical Equilibrium* module is in trial period.

During the academic year 1999-2000, the *Introductory* module was pilot-tested with two groups of General Chemistry students at UPR-RP. In the first semester, 21 undergraduate students enrolled in a section of General Chemistry voluntarily accepted to participate in the project. Of these only 13 worked partially or completely on the *Problem solving* section, the last part of the *Introductory* module. A total of 17 working sessions were held in this trial, and lasted two months (from October 4 through December 9 of 1999). These sessions were scheduled for two-hour periods on three-week days using PCs at the Natural Sciences Computer Center.

A total of 54 sessions were held during the second semester (from January 31 to March 24, 2000). Thirty-two out of 38 students (84%) completed the work on the module. In the second trial, the students used the I-MAC computers available in the Chemistry Department's Learning Resources Room. This room was specially prepared for the project and had 14 computers with the *Introductory* module installed. Twelve hours per week were scheduled for working on the module.

In both trials, every student sat individually at a desktop computer with the *Introductory* module installed in the computers CPUs. At the computer desk, each student was instructed to start the module and worked through individually. In the first trial, there were not written directions or related handouts. For the second trial, the professors wrote an instructions sheet to place besides each computer. The students were instructed to ask for the assistance of the professor in charge every time she or he needed and to point out any problem, error or misunderstanding that they found. In each trial, one of the coordinators was in the computer room. If the students had a question or difficulty raised a hand or asked the professor for assistance. Students used either their own calculator or the one provided in the module, a piece of paper (or notebook) and a pencil for doing the calculations.

Every time a student attended to a session, the professor in charge (Dr. Echegaray or Dr. Motta) checked the Attendance Sheet in order to verify which part of the module she or he was working on. She or he continued working through the module in the part where it was left. When the student finished to use the module, he or she notified the professor which part or problem completed. In the event that the student completed the *Introductory* module, she or he could leave the room or stay to answer the interview with the evaluator.

Students' completion rate and time in the module

In the first trial, the average of student attendance to the computer sessions was 4. The minimum number of students who attended to the sessions was 2 and the maximum 7. Eighteen students completed the *Math Skills and Graph* section. Ten students completed the work with the *Problem Solving* section by the end on the semester. However, three students did not finished but worked through at least five out of the nine problems. Students spent an average of 3 and 2.5 hours working on the *Math Skills* and *Problem Solving* sections of the module, respectively. In the second trial, the mean student attendance was approximately 3 and ranged from 16 to 0 students. By mid-semester, 32 finished the entire module. They spent approximately 3 and 3.5 hours, respectively, working on each section of the module.

Students' opinion about the module's features

In both trials, all students who used the *Introductory* module indicated that the instructions and explanations were clear, the examples were helpful and the vocabulary was easy to understand. The students indicated that they used all or almost all of the available information and helping devices in the screen. The most used devices in the *Math skills* section were "Factores de conversión" (Conversion factors), "Sugerencias" (Suggestion), "Calculadora" (Calculator) and "Fórmulas matemáticas" (Math formulae). In the *Problem Solving* section, they used more frequently "Factores de conversión"(Convertion factors), "Análisis" (Analysis), "Datos" (Data) and "Diagrama" (Diagram).

The intelligent feedback system was the most appraised feature of the module. About 90% of the students in both trials commented that the feedback messages were helpful ("ayudó") in giving some direction for reaching the correct answer. Table 4 shows a summary of the module's features and the percentage of students' responses in each trial.

Most of the users found that the exercises and problems were of medium difficulty ("ni fáciles ni díficiles"). In the *Math Skills* part, logarithms exercises were the most difficult for 82% of the students. For 50% of the students, scientific notation was the easiest part. In the *Problem Solving* part, students' opinion regarding the most difficult problem varied from problems 1, 2 and 3.

Relevance of the module for the students

More than 90% of the students in the first trial indicated that they were either very interested or interested in their work on the *Math skills* and *Problem Solving* sections. Sixty and fifty percent of the students in the first and second trial, respectively, choose that they were very interested in the *Problem Solving* section. In the two trials, nine out of ten students indicated that both sections of the module helped them a lot ("mucho" and "bastante") in improving their math and problem solving skills. For instance, two students commented that the module helped them "to refresh and improve the skills learned before and in the class". Most of the students commented that the *Problem Solving* section was the most helpful for the General Chemistry course. Because the format of the problems were similar to those encountered in the course.

Table 4. Student's percentage of agreement or responses to the module features in each trial.

Module features	Math skills and Graph section	Problem solving section
1. Instructions easy to understand	100[1] 100[2]	100 100
2. Very clear or clear explanations	100 79	100 82
3. Very useful or useful examples	100 100	100 89
4. Fair amount of examples or problems	90 96	90 100
5. Vocabulary easy to understand	100 96	70 85
6. Usage of all or almost all helping devices	100 100	100 100
7. Good response space	100 100	100 100
8. Very helpful feedback	91 89	78 82
9. Very attractive or attractive menu	100 100	100 96
10. Organized screen format	90 100	100 100
11. Good screen sequence	90 93	100 93
12. Fair or good amount of text in the screen	80 77	90 60
13. Very helpful diagrams	80 68	90 79
14. User is in control	100 93	100 93
15. Fair extension (length)	55 86	40 50
16. User very interested or interested	91 89	100 86

[1] Students responses in the first trial.
[2] Students responses in the second trial.

Students' evaluation of the module

Eighty percent of the students praised the module as excellent. The main features that they liked the most were the explanations, aids, screen display and color, drawings and feedback. One of the features that most disliked was the text extension (length) in the sections. In the interview responses, the students' comments were positive with regard to the *Math skills* section of the module: -"Es bueno para repasar las destrezas matemáticas" (It is good to review math skills), "Se lo recomendaría a otros estudiantes que no saben matemáticas" (I recommend it to students who don't know math). The most salient comment of the students with regard to the problem solving section were the drawings and its capability of making drawings related to the problem.

Students' suggestions to improve the module

Among the students suggestions to improve the *Introductory* module are the following:

1) A short test at the end of each section or at the end of the module,

2) More graphs problems and in other math skills,

3) Directions for using the module's calculator,

4) Directions for entering the responses,

5) Problems in order of difficulty,

6) Problems in other format, and

7) Explanations related to choose the appropriate graph.

These suggestions has been incorporated in the last version of the module.

Students' pre- and post-test scores

First trial

The pre-test was administered to 21 students and the post-test was answered by 13 students (who finished at least five problems in the *Problem solving* section). Both tests were administered during an extra period of class and lasted approximately 80 minutes. Using this very small sample, the Cronbach's internal consistency reliability indexes of the pre- and post-test scores were 0.78 and 0.84, respectively. The pre-test difficulty mean was approximately 0.70. and the post-test difficulty mean was near 77%. Although the test was relatively easy for the students in both test administrations, Logarithms and Graphics were the most difficult topics. The item difficulty means for each of the test parts are shown in Table 5. Table 6 shows the correlation indexes, mean and standard deviation (SD) of the participants' scores in the first trial.

Table 5. Pre- and post-test item difficulty means in the first trial

Test part	Item Identification	Pre-test item difficulty mean	Post-test item difficulty mean
Scientific notation	1-5	97	92
Equations	6-10	79	85
Proportions	11-15	88	89
Percentages	16-20	69	88
Logarithms	21-25	40	66
Graphs	26-30	45	43
Overall test difficulty mean		69.7	77.2

Table 6. Correlation indexes, mean and standard deviation (SD) of the scores in the first trial

Scores	Pre-test	Post-test	Final exam	Course grade	Mean	SD
Pre-test	1.00	0.18	0.75	0.86	20.1	3.41
Post-test	0.18	1.00	0.31	0.46	21.4	3.86
Final exam	0.75	0.31	1.00	0.84	116	15.53
Course grade	0.86	0.46	0.84	1.00	77.21	9.13

Non-significant differences were found between the pre- and post-test mean scores of the students in the six test-parts and overall. The scores on the pre-test correlate high and significantly with the final exam ($r=0.75$, $p<0.05$) and the course grade ($r=0.86$, $p<0.01$). Non-significant correlation indexes were found between the post-test data and the other scores.

Second trial

The pre- and post-test item responses of 32 students who worked through the *Introductory* module and of the 21 students in the comparison group were used in the statistical analysis. The descriptive statistics in the pre- and post-test of the experimental and comparison group were the following:

Group	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD	Final exam Mean	Final exam SD
Experimental	32	16.06	4.58	19.06	4.38	80.42	21.51
Comparison	21	14.81	4.93	15.14	4.75	67.78	24.40

The pre-test was administered to both groups in the first week of class and the post-test by mid-semester. The Cronbach's internal consistency reliability indexes were 0.76 in the pre-test and 0.70 in the post-test for the experimental group. For the comparison group the internal consistency reliability index of the scores was 0.80 in the pre- and 0.82 in the post- test. These statistics indicate a consistent pattern of students' responses to the tests, and hence, reliable test scores.

Table 7 shows the test-parts and their item difficulty means for the experimental and comparison group. The overall difficulty mean of the pre-test was 53% and 50% for the experimental and comparison group, respectively. This represents a medium difficulty pre-test for both groups. In the pre-test, the percentage of correct responses for both groups was closer in two out of seven test-parts (Equations and Problem solving). The most difficult parts in the pre-test for both groups were Logarithms and Problem solving.

The post-test overall mean difficulties for the experimental and comparison group are quite distant (64% and 50%, respectively). Apparently, for the experimental group the post-test was a bit easier than for the comparison group. In all the post-test parts, the percentage of correct responses of the experimental group was higher than of the comparison group. In the experimental group there is an increment in the percentage of students who answered correctly the test items in five parts, except the Ratio and proportion, and Graph items.

Table 7. Pre- and post-test results of the experimental and comparison group in the second trial

Test part	Item identification	Pre-test item difficulty mean	Post-test item difficulty mean
Scientific notation	1-4	72[A] 75[B]	89 75
Equations	5-8	61 61	72 65
Ratio and proportion	9-12	80 75	77 73
Percentages	13-16	55 50	78 50
Logarithms	17-20	30 24	50 35
Graphs	21-24	48 45	44 37
Problem solving	25-30	27 28	50 31
Overall difficulty mean		53 50	64 50

[A] Experimental group; [B] Comparison group

The t-tests statistics for pairwise comparisons showed significant differences between the means of the experimental and comparison groups in the post-test scores ($t=3.08$, $df= 51$, $p<.01$). Also, significant differences were found in the means of the experimental group pre- and post-tests scores ($t=-2.68$, $df=31$, $p<0.05$). Non-significant differences were found between the score means of both groups in the pre-test, and of the comparison group in the pre- and post- tests. These results indicate that the use of the *Introductory* module might influence the experimental group test performance.

Students' performance in the final exam

In the first trial, the mean score of the students in the General Chemistry final exam of the course was 116 and the standard deviation was 15.53. The General Chemistry professors constructed this exam, and the total score was 135. Significant correlation was found between the students' scores in pre-test and the final exam ($r=0.75$, $p<0.01$). Six out of ten students scored over the mean but all of them obtained total scores over 70% of the test.

In the second semester, the total score of the final exam was 140. The experimental group mean score was 80.42 whereas mean of the comparison group was 67.78. No significant differences were found in the final exam mean scores of the experimental and comparison groups. However, the mean score of the experimental group was higher than of the comparison group. In the experimental group, 15 out of 32 students (47%) scored over the group mean.

Students' performance in the General Chemistry Course

In the first trial, the average percentage in the General Chemistry Course of the 10 students who completed the module was approximately 77%. Nine out of ten students obtained an average grade over 70%. Only, the correlation between the pre-test scores and the course grade was significant and the highest ($r=0.86$, $p<0.01$). In the second trial, the course grade average of the experimental group was 70.37%. Seventeen students (53%) got an average percentage grade over the mean.

Conclusions

The evaluation findings of the project *Enhancement of problem solving and scientific reasoning skills through computerized General Chemistry modules* reveal that the activities were conducted as planned during the first year of implementation: (1) order and purchase hardware, authoring language and other materials; (2) designing the *Introductory* module and translating to programming language; and (3) piloting (in two trials) the *Introductory* module.

Overall, users' opinion regarding the *Introductory* module features was highly positive. Between 70% and 100% of the students gave affirmative responses to the inquired features such as clear instructions and explanations, useful examples, easy vocabulary, helpful feedback, good screen format, sequence and fair amount of text. Most of the students (80%) evaluate the module as excellent and, particularly, they pointed out the relevance of the *Problem Solving* section in the General Chemistry course. They commented that this section was the most helpful because the problems were somewhat similar to those presented in the first part of the course. Although, the students praised the entire module and the instructional experience, they made several suggestions towards the module improvement. The suggestions were attended in the second trial, and programming bugs were solved in the revised version of the module.

Despite of the above positive results of this evaluation, the differences in the pre- and post-test scores of the first trial group were not significant. Therefore, it is not possible to attribute the slight increment in the post-test scores to the students' work on the *Introductory* module. This result agrees with others related to the non-conclusive positive effect of CAI on student learning. However, it is important to point out the unexpected high and significant relation between the students pre-test scores, the final exam and the course grade. The sample of ten students who completed successfully the *Introductory* module obtained scores over 70% in the final test and satisfactory course grades.

The results of the second trial showed a better picture of the effect of the use of *Introductory* module towards improving student's achievement in General Chemistry. The experimental group scored higher in the post- test and in the final exam than the comparison group. This result supports the use of the module for improve students' performance in the General Chemistry course. Also, it agrees with others studies related to the positive relation of computer assisted instruction and student learning. However, it should be noticed that some extraneous variables might influence the scores of both groups such as (1) different teaching styles, (2) sample selection and assignment to the experimental and comparison group, (3) changes in testing, (4) students' attitudes towards the treatment, (5) coverage of the course material in the semesters, (6) students taking simultaneously other related courses such as Calculus II and Physics, and (7) treatment briefly applied. Thus, the results should be taken carefully.

On the basis of the evaluation results, some recommendations for improving the module future use and accessibility follows:

1. To prepare a handout with directions for the users which may include how to enter into the module, to write the answers in scientific notation and to use the module's bottoms.
2. To incorporate in the module a management system for monitoring its use, the frequency of student usage and how many times shoe he attempts to solve each problem.
3. To gain faculty evaluation regarding the module features.
4. To document systematically the activities of the project.

5. To administered (through the module or in paper) one or two set of exercises to the students at the end of each section on the *Introductory* module. The student should receive quick feedback on his or her responses. This also serves to collect information about the student immediate performance after the use of the module.
6. To train other General Chemistry faculty and teacher assistants in the use of the module.

Overall, the results of this formative evaluation indicate that the pilot phase of the project was effectively implemented and according to the proposal. The students positively highlighted several features of the *Introductory* module and its use. Thus, in light of the above evidence the project was conducted in the right direction towards its outcomes.

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Organization/Address: University of Puerto Rico PO Box 23187 San Juan, PR 00931-3187	Telephone: (787) 764-0000 Ext. 4401	Fax: (787) 792-6006
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